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SURFICIAL GEOLOGY ALONG THE SPOKANE RIVER, WASHINGTON AND ITS RELATIONSHIP TO THE METAL CONTENT OF SEDIMENTS

(IDAHO-WASHINGTON STATELINE TO LATAH CREEK CONFLUENCE)

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INTRODUCTION

The Spokane River flows westward into eastern Washington out of the northern end of Lake Coeur d'Alene in northern Idaho (figure 1). The river and lake lie downstream of the Coeur d'Alene mining district, where over 56 million metric tonnes of metal-enriched tailings were disposed into the Coeur d'Alene River between 1886 and 1968 (Long, 1998). Geochemical analyses of riverine sediments in the Spokane River by the Washington Department of Ecology (Johnson, 1999), the US Geological Survey (Grosbois and others, 2001; Box and others, in prep.) and a contractor for the Environmental Protection Agency (URS Greiner, 2000, 2001) have indicated that Spokane River sediments are variably enriched in metals derived from those tailings. In order to give some geologic context to this variable enrichment, we mapped the distribution and characteristics of unconsolidated deposits within and along the Spokane River in eastern Washington between the Idaho stateline and the confluence with Latah Creek about 32 km (20 miles) downstream and prepared a surficial geologic map (plates 1 through 8). Existing sample datasets for sediments and soils in and along the Spokane River are also located on the map and the surficial geologic unit that was sampled is noted in table 1.

The purpose of this study is (1) to document the geographic distribution of Holocene (deposited in the last 11,000 years) sedimentary lithologies in and along the Spokane River, (2) to document the downstream variation of metal contents (especially lead [Pb] and zinc [Zn]) by sedimentary lithology, and (3) to compare the metal contents of different sedimentary lithologies. This data is used to gain some understanding of the physical and chemical processes that control those metal contents. It is hoped this study can be used to guide potential future remedial actions aimed at reducing the biologic impact of metal-enriched sediments in this area. This work was undertaken in cooperation with the Washington Department of Ecology and the Environmental Protection Agency.

Methodology

Field work along the Spokane River corridor was undertaken between August 21 and September 1, 2000, when flow of the river was at its annual minimum (600-800 cfs). Page-size, 1:3000 scale, black-and-white prints made from the USGS digital orthophoto quarter-quadrangles (DOQQs; nominal scale 1:12000) were used as field sheets for mapping. One or both banks of the river were walked for most of the map area and the character of the surficial deposits was studied. Mappable units were defined based primarily on lithologic character and position relative to the inundated low-flow channel. The map area was subdivided into map units based on consistency and continuity of the lithologic character of the subareas, with a minimum polygon size of 50 square meters. Typically the area of a mapped unit may include patches of up to 20% of other lithologies than that in the unit description. Map units were transferred to the field sheets by inspection. Following the field work, the linework from the field sheets was used to draw attributed polygons in a shapefile (srgeounits.shp) on the DOQQ base (UTM, NAD27) in ArcView 3.1. Some of the linework was later revised after subsequent spot field visits.

The report begins with the presentation of the geologic setting of the Spokane River valley, especially the importance of its late Pleistocene history, deposits, and landforms. This is followed by a discussion of the hydrology of the river system and the effects of the several dams in and upstream of the map area. The Recent (last 11,000 years) and historic sedimentary deposits in and along the Spokane River (the main focus of this report) are then broadly discussed. The discussion then moves to the geochemistry of the Recent sedimentary deposits based on sampling for this report and on several other sample datasets. We first present relevant information about sampling methodologies, followed by a discussion of the variations of sediment trace element geochemistry and the relevance of interelement correlations. Finally, the more detailed descriptions of the individual surficial geologic map units are given. The three appendices give more information about the digital data available with this report.

GEOLOGIC BACKGROUND

Geomorphology of the Spokane River valley

The Spokane River flows into a wide alluvium-covered valley out of the north end of Lake Coeur d'Alene, a relatively narrow, bedrock-flanked, backflooded stream valley. Between the Washington-Idaho stateline and downtown Spokane, the Spokane River flows in a shallow (10-20 m, or 30-60 feet deep), incised inner valley within the wide (3-4 km, or 2-3 mile wide) flat alluvium-covered valley (figure 2). At Spokane Falls in downtown Spokane, the river plunges over a series of basaltic ledges (Miocene Columbia River basalts: Joseph, 1990), falling about 40 m (130 feet) in 0.8 km (0.5 mile). Between the base of Spokane Falls and the confluence with Latah Creek, the Spokane River cuts a 60 m (200 foot) deep valley through unconsolidated gravels. Latah Creek joins the river from the south, the first perennially flowing tributary downstream of Lake Coeur d'Alene.

The wide Spokane valley is underlain by coarse, late Pleistocene glacial outburst flood gravels that are as thick as 200 m (650 feet) and constitute the matrix of the Spokane Aquifer (Molenaar, 1988). Deposition of these gravels in the Rathdrum Prairie-Spokane valley resulted from huge, repeated glacial outburst floods emanating southward from the present location of Pend Oreille Lake (figure 1). A tongue of the continental ice sheet would advance southward into the valley of present-day Pend Oreille Lake, effectively damming the Clark Fork valley. Failure of the glacial ice dam caused catastrophic draining of the impounded lake waters in the Clark Fork valley. Repeated re-advance of the glacial tongue and failure of the glacial dams led to dozens of these glacial outburst floods. These massive floods (maximum flood discharge estimated to be about 600 million cubic feet per second [cfs] or over 100 times larger than the floodstage Amazon River at its mouth; O'Connor and Baker, 1992) repeatedly deposited coarse gravels in the Rathdrum Prairie-Spokane valley, building up the valley floor and damming all the tributary valleys to form lakes, the largest of which is Lake Coeur d'Alene. Only Lake Coeur d'Alene has perennial surface water outflow. All the other tributary lakes have surface outflow only at the highest water levels because of the permeable nature of the gravel dams.

The Spokane valley, generally devoid of surface drainage because of the permeable character of these glacial outburst flood deposits, preserves bedforms developed during the repeated late Pleistocene catastrophic glacial outburst floods (figure 3). These bedforms include the primary deepest channel (thalweg), interconnected secondary channels, intrachannel bars, channel margin bars, eddy bars, and erosional bedforms. The present surface features developed during the last (few?) outburst flood(s) between 13,000 and 11,000 years ago (Waitt, 1985). The outburst flood deposits in the thalweg consist of 3-5 m (10-16 foot) thick layers of cobble to boulder gravel with foreset layering inclined downstream (figure 4). Large-boulder lag horizons

(1-3 m diameter boulders) occur at the base of some of the layers. The Spokane River outflow from Lake Coeur d'Alene follows a secondary outburst flood channel until it intersects the primary thalweg channel west of the Idaho-Washington stateline. Further west the river mostly follows the outburst flood thalweg through the Spokane Valley, except for a segment above Upriver Reservoir where it follows a secondary outburst flood channel.

The incised inner valley within the wide Spokane valley was eroded by the Spokane River into the landscape left by the last of the glacial outburst floods. This incised inner valley consists of stream deposits within the active floodplain of the Spokane River, as well as two terrace levels above the present floodplain (three terrace levels between Spokane Falls and Latah Creek). The terraces represent earlier floodplain levels that were stranded by continued downcutting of the river channel. The surficial deposits of this incised inner valley, including the abandoned floodplain terraces, are the subject of this report and are mapped in plates 1 through 8.

Flow of the Spokane River

The Spokane River flows out of the northern end of Lake Coeur d'Alene. The flow rate of the Spokane River out of the lake is controlled by a bedrock-incised reach of the river at Post Falls, Idaho (figure 1). Unrestricted flow on the river closely correlates with the height of the water surface of Lake Coeur d'Alene. Three natural channels are cut through the bedrock at Post Falls. Since 1906 the three channels have been blocked by dams; the northern and southern dams are gated to allow for control of the lake elevation at selected heights (partially closed) or for free flow (open), while the middle dam is equipped with flow-through power turbines (maximum flow rate through turbines is 5000 cfs). Typically the dam gates are completely opened from December through early June and the lake level and Spokane River flow fluctuate, depending on the inflow rate to the lake. Lake levels and Spokane River flows typically rise due to spring snowmelt in April and May, and begin subsiding by early June. From early June to early September, the dam gates are fixed to control the lake elevation at 2125 feet (647.7 m) above sea level, causing the Spokane River outflow to gradually decline through the summer to annual minimum levels in late August and early September. From early September to early December the lake level is gradually lowered (and the Spokane River outflow rate increased) until the dam gates are completely opened and the lake adjusts to its natural level (where inflow to the lake equals outflow from the lake). Between December and March, it is not unusual for several winter-warming events to push the lake level and Spokane River flow up to spring-like levels for short periods. The annual hydrographs for Water Years 1997 and 1998 (relative high and low flow years, respectively) are shown for the Spokane River at Spokane in figure 5.

The USGS has operated the gage on the Spokane River at Spokane since 1891. A plot of the annual flow peaks since establishment of the gage in 1891 is shown in figure 6. The highest flow (49,000 cfs) was recorded in May of 1894 (prior to Post Falls dam) when the lake level was at 2134.6 feet (650.6 m). The next highest flow (47,100 cfs) occurred in December of 1933 (after Post Falls dam was constructed) when the lake level reached 2136 feet (651.1 m). The third and fourth highest flows occurred in January, 1974 (45,600 cfs) and in May of 1997 (42,600 cfs), respectively. Peak flow in the spring of 2000 was 27,500 cfs, slightly above the median value of 25,000 cfs and the highest since 1997. During the August, 2000 fieldwork, the high water marks of spring, 2000 and May, 1997 were readily identified in most locations. At a few places just east of Sullivan Road, the high water mark of January 1974 is still recognizable.

The Spokane River significantly interchanges water with the groundwater of the Spokane Aquifer (Molenaar, 1988). During intermediate to low flows on the river, the water is lost downward through the bed of the river into the underlying aquifer from the stateline to about Sullivan Rd. (figure 2), while water is gained into the river from the aquifer below Sullivan Rd. During low-flow periods, stream flow can triple between Post Falls and downtown Spokane due to inflow of groundwater to the river. When stream flow is increasing to high flow conditions, water percolates into the aquifer along the whole length of the river.

Three dams on the Spokane River are located within the map area: Upriver dam, Havermale Island (or Upper Falls) dam, and Monroe Street dam (figure 2). At each dam the reservoir height is controlled at an approximately fixed height by release of water through the associated power-generating turbines and either through a gated dam (Upriver and Havermale Island dams) or over a fixed dam (Monroe Street). At high flows the water surface elevation at the upstream end of the low-flow reservoirs rises because of increased inflow.

Surficial deposits along the Spokane River

The Spokane River flows over a cobble to boulder bed for most of its course between the Idaho stateline and its confluence with Latah Creek, except for a 0.8 km (0.5 mile) reach through downtown Spokane, where it flows over bedrock. As mentioned above, the channel is incised into a thick sequence of Pleistocene outburst flood gravels and the cobble-boulder bed is derived primarily from erosion of the flood gravel deposits. These flood gravels (especially the thalweg and secondary channel deposits) consist predominately of well-rounded, cobble-size materials, but clast sizes range from sand to 3 m (10 foot) diameter boulders. Silt and finer grainsize material is scarce in the Pleistocene flood channel deposits. In general, boulders with diameters greater than about 0.3 m (one foot) are too large to be moved by the present stream and remain as a lag deposit on the stream bed and banks as smaller clasts are moved around them. Where boulders greater than 0.3 m diameter are exposed, the environment is generally erosive, since deposition of smaller clasts would bury them. Conversely, areas of the river channel and floodplain with maximum clast size of less than one foot have been built up by riverine deposition of those clasts.

The river moves, sorts, and redeposits sediment in cycles ranging from one year to hundreds and even thousands of years. For the coarse bedload (coarse cobbles), movement and redeposition occurs during infrequent high flow events (10s to 100s of years between recurrence). Finer materials also move in more frequent, lower flow events (semi-annually to every few years) and are deposited over the bedforms constructed of coarser materials during the infrequent high flow events. At the finest grain sizes (clays), chemical and biologic precipitation, sorption, and flocculation play important roles in the creation of sedimentary particles and creation, transportation, and deposition of these particles can occur even at the lowest flows.

Excluding the lag deposits, the coarsest depositional materials on bars in the Spokane River are coarse cobbles (125-250 mm diameter clasts). In the high flow channel upstream of Harvard Road (figure 2; plates1, 2), accumulations ("bars") of coarse cobbles generally are present along the inside of gentle to sharp river bends. They are much less common but are locally present between Harvard Road and Upriver Reservoir; they are rare between the reservoir and the confluence with Latah Creek. Where bars are lacking, the erosional channel flanks are draped with a thin veneer of cobbles and/or finer deposits. Upstream of Harvard Road, the depositional bars consist of wide areas of deposited cobbles that are completely submerged at high flow and exposed at low flow. The channelward flank of each bar consists of recently rolled cobbles, and a cobble riffle occurs along part of the bar in the low flow channel.

The gravel bar deposits grow laterally as the channel migrates toward the opposite bank. The channel erodes the opposite bank as the bar grows, maintaining the channel cross-section. As the bar grows, the bar top away from the channelward flank begins to accumulate a thin veneer of sand ("floodplain sand") during high flow events (generally less than 0.6 m, or 2 feet, thick). Further lateral bar growth leads to the erosion of a shallow bar-top channel along the inner edge (distal from channel) of the sand-capped bar. Preserved terraces along the river channel represent older, sand-capped coarse-cobble bars that became stranded above flood level after renewed downcutting of the river channel. In a few places bars composed of gravels finer than coarse cobbles are present along the flanks of the river channel.

Sand deposits are not extensively present within or along the channel of the Spokane River. Sand deposits occur in three settings within the active floodplain of the Spokane River: (1) capping the flat top of coarse cobble, river margin bars (discussed above), (2) as a narrow, channelward-sloping band of beach sand near the high water line on one or both margins of the river, and (3) as smaller pockets of sand behind natural or manmade obstacles along the flank of the channel. Only a few deposits of sand in the third setting above extend down into the low flow channel; all other sand deposits are separated from the low-flow channel by gravel deposits.

The fine-grained fraction (fine sand-, silt-, and clay-sized fractions) of the sediment deposits in and along the Spokane River (the fractions analyzed for metal contents discussed subsequently) make up a small percentage of the total weight of most of the sample units in the map area (URS Greiner, 2000; Grosbois and others, 2001). This size fraction of the cobble and pebble units was generally not deposited during the peak flows that deposited the coarse framework grains but was deposited on the surface of that unit during the waning of the peak flows or even later. In some cases the fine fraction is scoured away from the surface of the cobble and pebble units during high velocity runoff flows and a new layer deposited as flow velocities diminish. Fine-grained material that has worked itself below the surface into the interstitial spaces between the cobbles or pebbles can be preserved, at least until the framework grains are mobilized. The silt and clay fraction of the sand deposits is generally deposited at the same time as the sand.

GEOCHEMISTRY OF THE SURFICIAL SEDIMENTS

Sampling methodology

During the field work, we collected grab samples of sand or finer material from 51 sites in the map area in sandwich-size (10 cm by 10 cm) Ziploc bags. These sample bags were shaken to allow the finer fraction to move to the bottom of the bag and that part of the sample was analyzed with a portable X-Ray Fluorescence (XRF) instrument by personnel from URS Corp, under contract with the Environmental Protection Agency (dataset URS-00 in table 1; URS Greiner, 2001). The rough size sorting within the sample bag prior to analysis leads us to approximate the analyzed size fraction in table 1 as less than 500 microns (medium-grained sand and finer). A subset of these locations was resampled by the URS personnel after gridding of the sample site, selecting 7 random sample points from the grid, and field sieving the sample to less than 175 microns (fine-grained sand and finer; dataset URS-01 in table 1; URS Greiner, 2001). About 10% of these samples were reanalyzed in the lab using EPA methods and protocols, which showed good agreement with the XRF data.

Two other sample datasets are included in table 1 and are briefly described here. The first consists of 35 samples collected by the USGS (dataset USGS-99 in table 1; A. Horowitz, USGS, written communication, 1999; Grosbois and others, 2001). Samples labeled "SRG-xx" were collected with a small dredge bucket from the submerged channel bottom using a small boat in October, 1998. Samples labeled "SRH-xx" were collected along the shoreline using a plastic trowel in October, 1998 and February, 1999. Two subsamples of these samples were analyzed: the less than 2000 micron fraction (very coarse sand and finer), and the less than 63 micron fraction (silt-sized and finer). Samples were analyzed using ICP-AES and AAS methodologies and instrumentation (Grosbois and others, 2001). The second dataset consists of 56 samples from 8 public recreation sites collected in the summer of 1999 by a contractor for the EPA (dataset URS-99 in table 1; URS Greiner, 2000). Samples were collected above the waterline from 0 to 12 inches depth and sieved to less than 175 microns for analysis. Samples were analyzed using EPA methods and protocols (URS Greiner, 2000).

Sample locations were derived by a variety of methods and are given in UTM, zone 11 coordinates (meters) relative to the North American datum of 1927 (NAD1927). For dataset URS-00, the locations were marked directly on 1:3000 scale prints of the DOQQs and subsequently digitized in ArcView 3.1. For dataset URS-01, sample locations were located using differential GPS instrumentation ((URS Greiner, 2001). For dataset USGS-99, sample locations were digitized in ArcView from copies of the 1:24,000 US Geological Survey topographic maps used as field sheets (A. Horowitz, written communication, 2000; M. Beckwith, written communication, 2000). For dataset URS-99, sample locations were transferred by inspection from field sketches (URS Greiner, 2000) to the DOQQs in ArcView.

The surficial map unit from which each sample was taken is listed in table 1. For those samples that we collected, the map unit was noted during sample collection. For all other samples the map unit was determined by plotting the sample locations on the surficial geologic map of plates 1-8 in ArcView 3.1 (associated ArcView shapefile srgeounits.shp is available on our website at http://geopubs.wr.usgs.gov/open-file/of02-xxx).

Variations in sediment trace element geochemistry

The metal contents of the fine fractions of sediment samples from the map area are quite variable (table 1). To illustrate this variability, the lead (Pb) and zinc (Zn) contents (in parts per million [ppm] dry weight) of samples are plotted separately by map unit against downstream position in figures 7 through 10. The grain size fraction of the sample that was analyzed is also indicated on the plots. The average Pb and Zn content of the fine fraction (the <175 micron fraction, and in some cases the <63 micron fraction) of each unit is illustrated in figure 11, which also lists the percentage of samples by unit which have Pb contents greater than 700 ppm.

A comparison of the Pb and Zn content of samples upstream and downstream of Upriver Dam is given in table 2.

The Pb contents of the finer fractions of the four coarse cobble gravel units are plotted against downstream position in figure 7. The vertical axis of Pb content in figures 7 and 8 is scaled in increments of 700 ppm because the human health risk assessment for the Spokane River in Washington (URS Greiner, 2000) used 700 ppm Pb in the fine fraction of sediment as the lower limit of concern. Pb contents of the fine fraction of silty cobble gravels (Qgcc3; figure 7d) are the highest of the cobble lithologies, with 61% of the less than 175 micron sample fractions having values above 700 ppm, with a mean concentration of 1021 ppm Pb. All but two of all the Spokane River sediment samples with Pb greater than 1400 ppm come from unit Qgcc3. This depositional unit is only present upstream of Sullivan Road (east of UTM East 486,000). By comparison the fine fraction of samples of the sandy cobble gravel unit (Qgcc2) have a mean concentration of 501 ppm Pb with 14% of the samples having values above 700 ppm (figure 11), all occurring upstream of Upriver dam. The average Pb and Zn content of samples of Qgcc2 downstream of Upriver Dam is 61-65% of samples upstream (table 2).

The Pb contents of the finer fractions of the four sand and pebble gravel units are plotted against downstream position in figure 8. Of the samples sieved to less than 175 micron, none of the coarse pebble gravel unit (Qgpc) samples have Pb above 700 ppm (although two of the <63 micron samples do), while a few samples (12%) of the fine pebble gravel (Qgpf) do (figure 11). Only 2% of the channel flank sand beach samples (unit Qsc) have fine fraction Pb content greater than 700 ppm (mean = 378 ppm), while 25% of the floodplain sand (Qsf) fine fraction samples have Pb content greater than 700 ppm (mean = 512 ppm). Again all of the sand and pebble gravel samples with more than 700 ppm Pb were recovered upstream of Upriver dam. However for the channel flank beach sand unit (Qsc), Pb and Zn contents of samples downstream from Upriver dam are not significantly lower than those upstream of the dam (91-92% of the upstream values; table 2). The mean Pb content of the fine fractions of 11 samples of terrace sand, vertically above the level of historic sand deposition (and downstream of Upriver Dam), is 25 ppm.

The Zn contents of the finer fractions of the four coarse cobble gravel units and the four sand and pebble gravel units are plotted against downstream position in figures 9 and 10, respectively. Zn contents of the finer fractions of the samples are considerably higher than Pb contents and range up to nearly 7000 ppm. All but a few samples with Zn greater than 2000 ppm were recovered from upstream of Upriver dam. Typically the fine fractions of the coarse cobble samples are higher in zinc than the fine fractions of the sand units (figure 11). By comparison the mean Zn content of the fine fractions of 12 samples of terrace sand, vertically above the level of historic sand deposition (and downstream of Upriver Dam), is 91 ppm.

Correlation of the Pb and Zn contents of the fine fractions of all the bed sediment samples is crude (figure 12). Also plotted on this diagram are samples of suspended sediment collected from the Spokane River during high flow conditions in May of 1997 (Box and others, in prep.). The compositions of these suspended sediment samples overlap with those of the higher Pb and Zn bed sediment samples. Much of the variation seen in figure 12 could result from mixing of sediment with composition similar to the suspended sediment with sediment with low Pb and Zn (like the terrace sand samples). The spread of sample compositions that fall below that two-component trend would require an additional component with high Zn but low Pb contents.

Detrital mixing of varying proportions of three such components could explain the spread of Pb and Zn compositions of the bed sediment samples.

To test the utility of such a mixing scenario, a 3-component mixing model was developed and is illustrated in figure 13 on a plot of Pb content against Zn/Pb ratio of the bed sediment samples. Three end-members (EM) are hypothesized: (1) a high Pb-high Zn end-member (EM1), similar to the most metal-enriched suspended sediment sample from spring of 1997 (Pb = 2500 ppm, Zn = 4000 ppm), (2) a low Pb-low Zn end-member (EM2), representative of background sediment exposed on the flanks of the Spokane River channel and similar to the mean of our analyses of Spokane River terrace sand (Pb = 25 ppm, Zn = 100 ppm), and (3) a high Zn-low Pb end-member (EM3), which, based on figure 12, must have a Zn content of at least 7000 ppm and a low Pb content (50 ppm). The high Zn-low Pb end-member may represent metals precipitated or flocculated from the dissolved state in the river water or upstream lake, either inorganically or biologically mediated, as has been shown to occur in the lower Coeur d'Alene River (Paulson, 1996) and in Lake Coeur d'Alene (Laurie Balistrieri, written communication, 2001). On figure 13 two example mixing lines of these three components are shown with the mixture percentages for several points noted along each line.

The compositional variation of the fine fraction of some of the surficial map units may be explained by their positions along these theoretical mixing lines. For instance, the fine fraction of the silty coarse cobble unit (Qgcc3: open circle symbol on figure 13), deposited during high-water in eddies along the high-water channel, has the highest percentage of the high-flow, suspended sediment end-member (ranging from 20-100%), which is metal-rich and derived primarily from the Coeur d'Alene River above Lake Coeur d'Alene (Box and others, in prep.). Conversely the fine fraction of the coarse cobble unit with little fines (Qgcc1: blackened circle symbol on figure 13), which generally occupies the lower elevation band just above the late summer, inundated low-flow channel, falls along two separate mixing lines on figure 13: (1) a mixing line with a decreasing metal-rich, high-flow suspended sediment component (5-50%) and an increasing components of background sediment and of the high-Zn end-member, and (2) mixing between the background sediment end-member (70-100%) and the high Zn end-member, with less than 5% of the metal-rich high flow suspended sediment end-member. These two mixing trends may represent sedimentation of fines on and between the cobbles (1) during waning spring flows when detrital metal-rich fines are still traversing Lake Coeur d'Alene from input by the Coeur d'Alene River, and (2) during summer flows when little detrital sediment is input into the lake by the Coeur d'Alene River, and fine suspended sediment derived from biologic or inorganic flocculation of metals dissolved in the water is generated either in Lake Coeur d'Alene or in the Spokane River and mixes with detrital background sediment in the Spokane River.

Although the two metal-rich sediment components (EM-1 and EM-3) are hypothesized ultimately to arrive in the Spokane River via the outflow from Lake Coeur d'Alene, these components can be deposited and remobilized a number of times in and along the Spokane River channel before arriving in a particular sediment deposit. How much of the enriched metal component of any sediment sample was derived directly from suspended sediment exiting Lake Coeur d'Alene immediately prior to deposition versus from sediment previously deposited in the Spokane River channel is not known. It is presumed that repeated recycling leads to more thorough mixing of the 3 sediment components toward some average mixture. The median Pb and Zn contents of all the samples in table 1 are 350 ppm Pb and 1400 ppm Zn, similar to the median of the channel margin sand unit (Qsc) samples. This median point would be produced by the following mixture of the three end-members: % EM1-%EM2-%EM3= 13-75-12.

CONCLUSIONS

For most of its course from the Idaho stateline to its confluence with Latah Creek, the Spokane River channel is incised into a thick sequence of Pleistocene outburst flood gravels and flows over a bed of cobbles to boulders recycled from the Pleistocene deposits. Within this incised valley set in the broader Spokane valley, mappable, surficial lithological units underlie the active channel and floodplain and inactive Recent terraces. Metal concentrations in the fine fraction of sediments that are exposed in the active channel and floodplain are considerably higher than in sediments exposed on the inactive recent terraces (up to 100 times higher in Pb). The high metal concentrations are derived from metal-enriched sediment from historic mining and milling activities in the Coeur d'Alene drainage basin upstream (Grosbois et al, 2001).

Each Spokane River lithologic unit has a distinct range of metal contents. The highest Pb and Zn contents are found in a silty cobble gravel unit (Qgcc1), found only upstream of Sullivan Road; 61% of the samples have more than 700 ppm Pb, the level of concern in the Spokane River human health risk assessment (URS Greiner, 2000). In contrast the lowest Pb and Zn contents within the active floodplain are found in the channel margin beach sand unit (Qsc), with only 2% of the samples exceeding 700 ppm Pb. For most of the units, a weak trend of decreasing Pb and Zn content downstream versus upstream of Upriver dam is suggested by the plots of figures 7-10. However for the unit with the most samples for comparison (Qsc), samples downstream of the dam average 91-92% of the Pb and Zn content of those upstream (table 2).

The variation in metal content in the Spokane River sediment samples can be modeled as resulting from the detrital mixing of 3 components: (1) metal-enriched suspended sediment derived from the Coeur d'Alene River basin after transiting Lake Coeur d'Alene, (2) erosion of sediments deposited before upstream mining from the banks of the Spokane River, and (3) biologically or inorganically flocculated sediment with metals precipitated from solution either in Lake Coeur d'Alene or the Spokane River. It is presumed that the composition of a particular sediment results both from recycling of previously deposited detrital mixtures, as well as from input of new end-member components.

DESCRIPTION OF MAP UNITS

UNCONSOLIDATED DEPOSITS

Rationale for division of surficial map units

On the surficial geologic map of plates 1 through 8, surficial deposits along the Spokane River are broadly divided into 3 categories: (1) deposits submerged within the low-flow channel (units beginning with "Qc-"), and (2) gravel and sand deposits above the low-flow channel that are within the active (last few hundred years) high-water floodway (units beginning with "Qg-" and "Qs-", respectively), and (3) terrace deposits above the level of active flooding (units beginning with "Qt-"). Deposits within the submerged low-flow channel were not directly mapped but are subdivided based on whether the reach is pooled ("Qcp") or is riffled ("Qcr") or is inundated by damming ("Qci"). If boulders or cobbles are emergent across the low-flow channel, a "b" or a "c" is added to the pooled or riffled designation. Gravel deposits above the low-flow channel are designated "Qg-" and followed by modifying initials to denote clast size and variations in the fine fraction. Sand deposits are designated "Qs" and modified by their position relative to the sloping channel ("Qsc" for channel flank and "Qsf" for floodplain bench). Finally terrace deposits (generally capped by sand) are correlated with elevation above maximum flood level and numbered from lowest to highest (Qts1, Qts2, etc.). As is the convention with geologic map units, the first letter of the unit abbreviation ("Q") indicates the age of the unit, which in this case is Quaternary.

Qsc **Sand, sloping channel flank beach deposit** Coarse to fine sand underlying a gently channelward sloping surface. Where separated from the low-flow channel by a coarse cobble unit, the surface may support grass, brush, or Ponderosa pines. Up to 50% of the surface area of unit may be coarse cobbles. Percentage of interstitial silt and finer material varies from 0 to 20%. Thickness is variable, but is generally less than 30 cm. A small portion of this map unit may not have been inundated since the onset of mining in the Coeur d'Alene mining district in 1886.

Qsf **Sand, floodplain bench deposit** Coarse to fine sand underlying a generally horizontal surface adjacent to the channelward sloping surface adjacent to the low-flow channel. Unit typically supports a growth of grass. Up to 50% of the surface area may consist of coarse cobbles. Percentage of interstitial silt and finer material varies from 0 to 20%. Thickness is variable, but is generally less than 30 cm. A small portion of this map unit may not have been inundated since the onset of mining in the Coeur d'Alene mining district in 1886.

Qgpf **Gravel, fine pebble (2-20 mm)** Fine pebble gravel forming bars or in sloping channel flank deposits. Commonly grades into or is intermixed with coarse pebble gravel. Percentage of interstitial silt and finer material varies from 0 to 10%. Channel flank deposits between Myrtle Pt. and Argonne St. and between Greene St. and Division St.

have 10-50% coarse cobble to boulders. Those particular deposits are localized just upstream of the low-flow slackwater pools behind the in-channel dams at Upriver dam and at Havermale Island, respectively, where backwater effects reduce current velocities during high flow.

Qgpc **Gravel, coarse pebble (20-64 mm)** Coarse pebble gravel forming bars or in sloping channel flank deposits. Commonly grades into or is intermixed with fine pebble gravel. Percentage of interstitial silt and finer material varies from 0 to 10%.

Qgcf **Gravel, fine cobble (64-125 mm)** Fine cobble gravel forming unvegetated bars in or along the low-flow channel. Moderately to well-sorted with <5% silt and finer material. In-channel bars of this unit near Myrtle Pt. are vegetated and probably inactive.

Qgcc1 **Gravel, coarse cobble and boulder (>125 mm), with little fines** Coarse cobble gravel and intermixed boulders with less than 15% of surface area covered by sand and finer sediment. This unit typically flanks the low-flow inundated channel.

Qgcc2 **Gravel, coarse cobble and boulder (>125 mm), with patches of sand** Coarse cobble gravel and intermixed boulders with greater than 15% but less than 50 % of the surface area covered by sand, which contains little (<10%?) silt and finer sediment. Identified in the field by the sandy character of the intercobble surface and by the lack of a "flag" of visible dust that settles slowly when a shovelful of dry sand is tossed in the air.

Qgcc3 **Gravel, coarse cobble and boulder (>125 mm), with patches of silt** Coarse cobble gravel and intermixed boulders with greater than 15% but less than 50 % surface area covered by sand, which contains a significant component (>10%) of silt and finer sediment. Identified in the field by the silty character of the intercobble surface and by the "flag" of visible dust that settles slowly when a shovelful of dry sand is tossed in the air. Only present upstream of Sullivan Road.

Qcrc **Cobble riffle in low-flow channel** Submerged cobble bar in low-flow channel over which the river gradient increases to form a riffle.

Qcrb **Boulder riffle in low-flow channel** Channel bed with emergent boulders occurring irregularly across a riffled reach of the low-flow channel.

Qcpb **Low-flow channel pool with emergent boulders** Channel bed with emergent boulders occurring irregularly across a pooled reach of the low-flow channel.

Qcp **Low-flow channel pool** Submerged channel bed in pooled (non-riffled) reaches of the low-flow channel, generally underlain by coarse cobble and boulder gravel with little interstitial sand and finer sediment.

Qci **Channel bed beneath impounded reservoirs** Submerged channel bed beneath the reservoir waters in impounded reaches of the channel behind dams across the Spokane River (as observed in low-flow periods). Impounding dams include Monroe Street dam, Havermale Island dam, and Upriver dam. Character of bed sediment probably similar to that of Qcp but with more fines.

Qcb **Channel, scoured bedrock** High water channel bed underlain by scoured bedrock surface.

Qts1 **Sand and gravel deposits of the first (lowest) terrace** Coarse to fine sand overlying coarse cobbles and underlying a generally horizontal surface 5-10 feet above the active floodplain bench. Surface is typically covered by grass. Up to 50% of the surface area may consist of coarse cobbles. Percentage of interstitial silt and finer material in the surficial sand deposit varies from 0 to 20%. Sand thickness is variable, but is generally less than 30 cm.

Qts2 **Sand and gravel deposits of the second terrace** Coarse to fine sand overlying coarse cobbles and underlying a generally horizontal surface 15-25 feet above the active floodplain bench. Surface is typically covered by grass. Up to 50% of the surface area may consist of coarse cobbles. Percentage of interstitial silt and finer material in the surficial sand deposit varies from 0 to 20%. Sand thickness is variable, but is generally less than 30 cm.

Qts3 **Sand and gravel deposits of the third terrace** Coarse to fine sand overlying coarse cobbles and underlying a generally horizontal surface 40-50 feet above the active floodplain bench. Only present downstream of Spokane Falls. Surface is typically covered by grass. Up to 50% of the surface area may consist of coarse cobbles. Percentage of interstitial silt and finer material in the surficial sand deposit varies from 0 to 20%. Sand thickness is variable, but is generally less than 30 cm.

Qaf **Artificial fill rock** Artificially placed rock aggregate comprising road embankments, bridge abutments, and streambank riprap.

Acknowledgements

This work was partially funded by a cooperative agreement with the Washington Department of Ecology and by an interagency agreement with the Environmental Protection Agency. Discussions with John Roland of the Washington Department of Ecology were important in initiating this project and in refining the scope and approach of the study. Mary Jane Nearman of the Environmental Protection Agency is thanked for instigating an additional geochemical sampling program in coordination with our field work. Kara Steward and Jeff Franklin of URS Greiner, Inc. are thanked for their help and coordination in the field. We thank Arthur Horowitz and Mike Beckwith of the US Geological Survey for clarifications in response to our queries about their earlier geochemical sampling program.

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Table 1: Geochemical data for sediment samples from the Spokane River in the map area.

SAMPLE_ID	GRAINSIZE	DATASET	UTM27E	UTM27N	MAP_UNIT	Pb_ppm	Zn_ppm
SRG-37	<2000 um	USGS-99	484785	5280161	Qcp	100	510
SRG-38	<2000 um	USGS-99	483855	5280508	Qcp	150	730
SRG-39	<2000 um	USGS-99	483482	5280786	Qcp	160	730
SRG-40	<2000 um	USGS-99	481653	5282490	Qcp	170	1200
SRG-41	<2000 um	USGS-99	479988	5281631	Qcp	350	900
SRG-42	<2000 um	USGS-99	477446	5282048	Qci	360	2300
SRG-43	<2000 um	USGS-99	476717	5282137	Qci	21	650
SRG-44	<2000 um	USGS-99	475482	5281092	Qci	200	970
SRG-45	<2000 um	USGS-99	475753	5281184	Qci	130	1200
SRG-46	<2000 um	USGS-99	471643	5280276	Qcp	110	800
SRH-02	<2000 um	USGS-99	491723	5280890	Qgcc1	1200	1700
SRH-03	<2000 um	USGS-99	488532	5280365	Qgcc1	420	1200
SRH-04	<2000 um	USGS-99	485311	5279750	Qgcc1	200	870
SRH-05	<2000 um	USGS-99	496295	5282510	Qgcc1	430	2800
SRH-06	<2000 um	USGS-99	466296	5277588	Qgcc1	33	64
SRH-14	<2000 um	USGS-99	496145	5282487	Qgcc1	210	960
SRH-15	<2000 um	USGS-99	495878	5282393	Qgcc1	760	2000
SRH-15a	<2000 um	USGS-99	495878	5282393	Qgcc1	760	1900
SRH-16	<2000 um	USGS-99	494870	5281728	Qgcc3	1500	2000
SRH-17	<2000 um	USGS-99	493021	5280832	Qsc	370	2000
SRH-18	<2000 um	USGS-99	491961	5280963	Qsc	250	1000
SRH-19	<2000 um	USGS-99	491830	5280976	Qgcc1	500	1200
SRH-20	<2000 um	USGS-99	489648	5280760	Qgcc1	460	1700
SRH-21	<2000 um	USGS-99	488609	5280275	Qgpc	410	1600
SRH-21a	<2000 um	USGS-99	488609	5280275	Qgpc	1100	2700
SRH-22	<2000 um	USGS-99	488554	5280366	Qgcc1	510	3200
SRH-23	<2000 um	USGS-99	486973	5280376	Qgcc3	330	1300
SRH-24	<2000 um	USGS-99	486864	5280410	Qgcc1	430	1600
SRH-25	<2000 um	USGS-99	485487	5279627	Qgcc1	170	840
SRH-26	<2000 um	USGS-99	485349	5279729	Qgcc1	150	730
SRH-26a	<2000 um	USGS-99	485349	5279729	Qgcc1	140	720
SRH-27	<2000 um	USGS-99	484655	5280255	Qgcc1	200	990
SRH-28	<2000 um	USGS-99	483416	5280963	Qgcc1	150	810
SRH-29	<2000 um	USGS-99	482410	5281855	Qgcc1	370	1600
SRH-30	<2000 um	USGS-99	482174	5282192	Qgcc1	230	750
SRG-38	<63 um	USGS-99	483855	5280508	Qcp	770	2400
SRG-39	<63 um	USGS-99	483482	5280786	Qcp	750	2800
SRG-40	<63 um	USGS-99	481653	5282490	Qcp	470	3600
SRG-41	<63 um	USGS-99	479988	5281631	Qcp	2200	5300
SRG-42	<63 um	USGS-99	477446	5282048	Qci	320	2100
SRG-43	<63 um	USGS-99	476717	5282137	Qci	36	1900
SRG-44	<63 um	USGS-99	475482	5281092	Qci	1100	3400
SRG-45	<63 um	USGS-99	475753	5281184	Qci	460	2800
SRG-46	<63 um	USGS-99	471643	5280276	Qcp	550	3000
SRH-02	<63 um	USGS-99	491723	5280890	Qgcc1	2900	4800
SRH-03	<63 um	USGS-99	488532	5280365	Qgcc1	1300	3400
SRH-04	<63 um	USGS-99	485311	5279750	Qgcc1	1100	3200
SRH-05	<63 um	USGS-99	496295	5282510	Qgcc1	540	6400

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SAMPLE_ID	GRAINSIZE	DATASET	UTM27E	UTM27N	MAP_UNIT	Pb_ppm	Zn_ppm
SRH-06	<63 um	USGS-99	466296	5277588	Qgcc1	30	100
SRH-14	<63 um	USGS-99	496145	5282487	Qgcc1	690	2100
SRH-15	<63 um	USGS-99	495878	5282393	Qgcc1	690	1800
SRH-15a	<63 um	USGS-99	495878	5282393	Qgcc1	650	1700
SRH-16	<63 um	USGS-99	494870	5281728	Qgcc3	3500	4200
SRH-17	<63 um	USGS-99	493021	5280832	Qsc	1100	5500
SRH-18	<63 um	USGS-99	491961	5280963	Qsc	930	2300
SRH-19	<63 um	USGS-99	491830	5280976	Qgcc1	1300	2800
SRH-20	<63 um	USGS-99	489648	5280760	Qgcc1	580	2200
SRH-21	<63 um	USGS-99	488609	5280275	Qgpc	720	2700
SRH-21a	<63 um	USGS-99	488609	5280275	Qgpc	1400	
SRH-22	<63 um	USGS-99	488554	5280366	Qgcc1	830	3100
SRH-23	<63 um	USGS-99	486973	5280376	Qgcc3	530	1600
SRH-24	<63 um	USGS-99	486864	5280410	Qgcc1	1040	3800
SRH-25	<63 um	USGS-99	485487	5279627	Qgcc1	770	2600
SRH-26	<63 um	USGS-99	485349	5279729	Qgcc1	700	3600
SRH-26a	<63 um	USGS-99	485349	5279729	Qgcc1	730	3300
SRH-27	<63 um	USGS-99	484655	5280255	Qgcc1	730	2700
SRH-28	<63 um	USGS-99	483416	5280963	Qgcc1	820	3000
SRH-29	<63 um	USGS-99	482410	5281855	Qgcc1	770	3200
SRH-30	<63 um	USGS-99	482174	5282192	Qgcc1	930	2200
CUA201-101	<175 um	URS-99	494946	5281710	Qgcc3	719	2190
CUA201-102	<175 um	URS-99	494901	5281661	Qgcc1	1310	2420
CUA201-103	<175 um	URS-99	494964	5281755	Qgcc3	2360	3230
CUA201-104	<175 um	URS-99	494885	5281710	Qgcc3	656	2040
CUA201-105	<175 um	URS-99	494954	5281782	Qgcc3	2350	3320
CUA201-106	<175 um	URS-99	494909	5281725	Qgcc3	867	2490
CUA201-107	<175 um	URS-99	494931	5281760	Qgcc3	1590	3270
CUA202-101	<175 um	URS-99	491640	5280884	Qgcc1	479	2020
CUA202-102	<175 um	URS-99	491648	5280889	Qgcc1	328	1880
CUA202-103	<175 um	URS-99	491647	5280897	Qgcc1	484	2340
CUA202-104	<175 um	URS-99	491647	5280904	Qgpf	379	2090
CUA202-105	<175 um	URS-99	491647	5280911	Qgpf	503	2140
CUA202-106	<175 um	URS-99	491647	5280918	Qgpf	534	2480
CUA202-107	<175 um	URS-99	491647	5280924	Qgpf	261	1430
CUA203-101	<175 um	URS-99	491690	5280805	Qgcc1	1070	2640
CUA203-102	<175 um	URS-99	491690	5280799	Qsc	234	2180
CUA203-103	<175 um	URS-99	491690	5280795	Qsc	146	1570
CUA203-104	<175 um	URS-99	491690	5280791	Qsc	154	1180
CUA203-105	<175 um	URS-99	491690	5280788	Qsc	306	1770
CUA203-106	<175 um	URS-99	491690	5280784	Qsc	326	1360
CUA203-107	<175 um	URS-99	491690	5280780	Qsc	335	1500
CUA204-101	<175 um	URS-99	488531	5280368	Qgcc1	116	1990
CUA204-102	<175 um	URS-99	488537	5280378	Qgcc1	106	1360
CUA204-103	<175 um	URS-99	488546	5280380	Qgcc2	822	2590
CUA204-104	<175 um	URS-99	488552	5280377	Qgcc2	647	2610
CUA204-105	<175 um	URS-99	488557	5280375	Qgcc2	714	2490
CUA204-106	<175 um	URS-99	488562	5280373	Qgcc2	537	3470

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SAMPLE_ID	GRAINSIZE	DATASET	UTM27E	UTM27N	MAP_UNIT	Pb_ppm	Zn_ppm
CUA204-107	<175 um	URS-99	488563	5280356	Qgcc1	404	4880
CUA205-101	<175 um	URS-99	486920	5280371	Qgcc1	799	2440
CUA205-102	<175 um	URS-99	486920	5280369	Qgpf	529	4020
CUA205-103	<175 um	URS-99	486920	5280367	Qgpf	771	4450
CUA205-104	<175 um	URS-99	486920	5280365	Qgpf	531	3860
CUA205-105	<175 um	URS-99	486919	5280363	Qgpf	1040	2930
CUA205-106	<175 um	URS-99	486920	5280360	Qgpf	498	3030
CUA205-107	<175 um	URS-99	486919	5280358	Qgpf	772	2990
CUA206-101	<175 um	URS-99	481805	5282567	Qgcc1	88	266
CUA206-102	<175 um	URS-99	481801	5282559	Qgcc1	73	365
CUA206-103	<175 um	URS-99	481813	5282556	Qgcc1	173	592
CUA206-104	<175 um	URS-99	481810	5282563	Qgcc1	174	614
CUA206-105	<175 um	URS-99	481814	5282563	Qgcc1	98	228
CUA206-106	<175 um	URS-99	481801	5282565	Qgcc1	34	119
CUA206-107	<175 um	URS-99	481809	5282560	Qgcc1	112	254
CUA208-101	<175 um	URS-99	476892	5282168	Qts2	30	100
CUA208-102	<175 um	URS-99	476891	5282170	Qts2	25	74
CUA208-103	<175 um	URS-99	476890	5282173	Qts2	25	88
CUA208-104	<175 um	URS-99	476888	5282176	Qts2	55	172
CUA208-105	<175 um	URS-99	476887	5282179	Qts2	40	82
CUA208-106	<175 um	URS-99	476886	5282182	Qts2	18	51
CUA208-107	<175 um	URS-99	476885	5282184	Qts2	21	49
CUA209-101	<175 um	URS-99	465731	5278318	Qgcc1	15	69
CUA209-102	<175 um	URS-99	465725	5278326	Qts1	15	78
CUA209-103	<175 um	URS-99	465726	5278321	Qts1	19	91
CUA209-104	<175 um	URS-99	465735	5278324	Qgcc1	13	78
CUA209-105	<175 um	URS-99	465716	5278334	Qts1	16	78
CUA209-106	<175 um	URS-99	465736	5278315	Qgcc1	27	142
CUA209-107	<175 um	URS-99	465710	5278332	Qts1	13	66
JR1	<500 um	URS-00	495294	5281740	Qgcc1	-39	224
JR2	<500 um	URS-00	495310	5281777	Qsf	500	1600
JW01	<500 um	URS-00	495605	5282056	Qsf	444	1510
JW02	<500 um	URS-00	495555	5282048	Qsf	-63	106
JW03	<500 um	URS-00	495316	5281820	Qsf	282	944
JW04	<500 um	URS-00	494247	5281484	Qts2	61	126
JW06	<500 um	URS-00	488722	5280360	Qgcc2	426	1600
JW07	<500 um	URS-00	488793	5280398	Qts1	-54	628
JW09	<500 um	URS-00	487268	5280467	Qsc	188	680
JW10	<500 um	URS-00	495276	5281807	Qsf	122	1580
JW11	<500 um	URS-00	495751	5282237	Qsf	77	-78
JW12	<500 um	URS-00	486399	5279593	Qsf	173	444
JW13	<500 um	URS-00	486191	5279462	Qsf	101	532
JW14	<500 um	URS-00	486172	5279479	Qsf	-62	253
JW15	<500 um	URS-00	486449	5279956	Qgcc1	182	682
JW16	<500 um	URS-00	486431	5279964	Qsf	122	405
JW17	<500 um	URS-00	486425	5279979	Qsf	281	556
JW18	<500 um	URS-00	486414	5279986	Qsf	-59	71
JW19	<500 um	URS-00	486194	5279449	Qsf	-58	238

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SAMPLE_ID	GRAINSIZE	DATASET	UTM27E	UTM27N	MAP_UNIT	Pb_ppm	Zn_ppm
DA01-02	<175 um	URS-01	496923	5282442	Qsc	339	1860
DA01-03	<175 um	URS-01	496913	5282458	Qsc	123	5480
DA01-04	<175 um	URS-01	496912	5282440	Qsc	205	955
DA01-05	<175 um	URS-01	496923	5282444	Qsc	230	2020
DA01-05	<175 um	URS-01	496923	5282444	Qsc	300	2040
DA01-06	<175 um	URS-01	496911	5282437	Qsc	201	748
DA01-07	<175 um	URS-01	496907	5282448	Qsc	393	1440
DA03-01	<175 um	URS-01	496217	5282566	Qgcc3	546	1490
DA03-02	<175 um	URS-01	496224	5282565	Qgcc3	744	1990
DA03-03	<175 um	URS-01	496236	5282567	Qsc	396	1440
DA03-04	<175 um	URS-01	496215	5282574	Qgcc3	506	1910
DA03-05	<175 um	URS-01	496231	5282567	Qsc	410	1980
DA03-06	<175 um	URS-01	496223	5282570	Qsc	417	1810
DA03-06	<175 um	URS-01	496223	5282570	Qsc	369	1790
DA03-07	<175 um	URS-01	496225	5282578	Qsc	312	1460
DA04-01	<175 um	URS-01	495485	5281945	Qsc	-46	155
DA04-02	<175 um	URS-01	495494	5281942	Qsc	-50	180
DA04-03	<175 um	URS-01	495501	5281961	Qsc	168	805
DA04-03	<175 um	URS-01	495501	5281961	Qsc	168	786
DA04-04	<175 um	URS-01	495503	5281952	Qsc	-44	147
DA04-05	<175 um	URS-01	495493	5281953	Qsc	46	143
DA04-06	<175 um	URS-01	495488	5281954	Qsc	105	624
DA04-07	<175 um	URS-01	495484	5281949	Qsc	102	468
DA05 0-2	<175 um	URS-01	495498	5281910	Qsc	191	631
DA05 11-14	<175 um	URS-01	495498	5281910	Qsc	-43	455
DA05 14-17	<175 um	URS-01	495498	5281910	Qsc	-43	437
DA05 24-27	<175 um	URS-01	495498	5281910	Qsc	-43	244
DA05 4-7	<175 um	URS-01	495498	5281910	Qsc	536	1320
DA06-01	<175 um	URS-01	495275	5281830	Qsf	751	1740
DA06-02	<175 um	URS-01	495276	5281828	Qsf	938	4580
DA06-03	<175 um	URS-01	495276	5281826	Qsf	652	1710
DA06-04	<175 um	URS-01	495278	5281828	Qsf	1030	2310
DA06-05	<175 um	URS-01	495267	5281826	Qsf	517	1660
DA06-06	<175 um	URS-01	495279	5281827	Qsf	690	1730
DA06-06	<175 um	URS-01	495279	5281827	Qsf	704	1680
DA06-07	<175 um	URS-01	495273	5281826	Qsf	730	2150
DA07 0-3	<175 um	URS-01	495274	5281803	Qsf	440	1660
DA07 19-23	<175 um	URS-01	495274	5281803	Qsf	241	2620
DA07 23-40	<175 um	URS-01	495274	5281803	Qsf	56	842
DA07 48-73	<175 um	URS-01	495274	5281803	Qsf	-45	273
DA07 5-8	<175 um	URS-01	495274	5281803	Qsf	2280	4210
DA07 70-98	<175 um	URS-01	495274	5281803	Qsf	-45	258
DA08-01	<175 um	URS-01	495238	5281833	Qgpc	304	1120
DA08-01	<175 um	URS-01	495238	5281833	Qgpc	265	1120
DA08-02	<175 um	URS-01	495232	5281815	Qgpc	312	1180
DA08-03	<175 um	URS-01	495235	5281803	Qgpc	293	1080
DA08-04	<175 um	URS-01	495235	5281789	Qgpc	376	1430
DA08-05	<175 um	URS-01	495232	5281776	Qgpc	268	1050

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Table 1: Geochemical data for sediment samples from the Spokane River in the map area.

SAMPLE_ID	GRAINSIZE	DATASET	UTM27E	UTM27N	MAP_UNIT	Pb_ppm	Zn_ppm
JW20	<500 um	URS-00	484263	5280403	Qsf	-62	170
JW21	<500 um	URS-00	481832	5282445	Qsc	492	1560
JW22	<500 um	URS-00	481669	5282429	Qgpf	85	437
JW23	<500 um	URS-00	481502	5282061	Qsc	480	1310
JW24	<500 um	URS-00	481343	5282004	Qgpf	-60	595
JW25	<500 um	URS-00	481284	5281932	Qgpf	74	374
JW26	<500 um	URS-00	480200	5281612	Qsf	159	700
JW27	<500 um	URS-00	480120	5281629	Qsf	502	1440
JW28	<500 um	URS-00	480523	5281752	Qsf	114	728
JW29	<500 um	URS-00	480095	5281678	Qgpf	537	2000
JW30	<500 um	URS-00	480015	5281662	Qgpf	528	1830
JW31	<500 um	URS-00	474974	5280719	Qgcc1	99	458
JW32	<500 um	URS-00	474751	5280482	Qsc	383	1890
JW33	<500 um	URS-00	473874	5280192	Qsc	372	1520
JW34	<500 um	URS-00	473071	5280302	Qsc	91	665
JW35	<500 um	URS-00	472174	5280548	Qgpf	109	866
JW36	<500 um	URS-00	471680	5280343	Qgpf	132	1050
JW37	<500 um	URS-00	471014	5279657	Qsc	120	847
JW38	<500 um	URS-00	470784	5279114	Qgpf	158	992
JW39	<500 um	URS-00	471456	5280187	Qgpf	107	769
JW40	<500 um	URS-00	471739	5280303	Qgpf	229	1150
JW41	<500 um	URS-00	472258	5280490	Qgpf	147	748
JW42	<500 um	URS-00	473448	5280157	Qgcc2	206	981
JW43	<500 um	URS-00	466845	5278337	Qsc	-58	930
JW44	<500 um	URS-00	467401	5278441	Qsc	78	298
JW45	<500 um	URS-00	467120	5278329	Qsc	99	848
JW46	<500 um	URS-00	466365	5278285	Qgcc2	148	712
JW48	<500 um	URS-00	496215	5282573	Qgcc3	504	1760
JW49	<500 um	URS-00	496234	5282567	Qsc	182	1000
JW50	<500 um	URS-00	465839	5279957	Qsc	-67	252
SB7B 130-165	<500 um	URS-00	495291	5281747	Qgpc	163	690
SB7B 165-200	<500 um	URS-00	495291	5281747	Qgpc	-43	278
CUA203-01	<175 um	URS-01	491647	5280754	Qsc	535	1990
CUA203-01	<175 um	URS-01	491647	5280754	Qsc	513	2100
CUA203-02	<175 um	URS-01	491624	5280748	Qsc	210	491
CUA203-03	<175 um	URS-01	491675	5280785	Qsc	433	2770
CUA203-04	<175 um	URS-01	491629	5280767	Qgcc1	580	2210
CUA203-05	<175 um	URS-01	491690	5280789	Qsc	91	834
CUA203-06	<175 um	URS-01	491611	5280736	Qsc	161	718
CUA203-07	<175 um	URS-01	491668	5280771	Qsc	489	1300
CUA204-01	<175 um	URS-01	488559	5280364	Qgcc1	77	4850
CUA204-02	<175 um	URS-01	488561	5280369	Qgcc2	570	3190
CUA204-03	<175 um	URS-01	488549	5280370	Qgcc1	137	3420
CUA204-04	<175 um	URS-01	488540	5280376	Qgcc1	501	2210
CUA204-05	<175 um	URS-01	488547	5280382	Qgcc2	377	1310
CUA204-06	<175 um	URS-01	488531	5280381	Qgcc1	159	1240
CUA204-07	<175 um	URS-01	488557	5280372	Qgcc2	463	1870
DA01-01	<175 um	URS-01	496930	5282436	Qsc	-56	2730

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Table 1: Geochemical data for sediment samples from the Spokane River in the map area.

SAMPLE_ID	GRAINSIZE	DATASET	UTM27E	UTM27N	MAP_UNIT	Pb_ppm	Zn_ppm
DA16-07	<175 um	URS-01	488599	5280276	Qgpc	69	818
DA17-01	<175 um	URS-01	486189	5279469	Qsf	129	541
DA17-02	<175 um	URS-01	486184	5279457	Qsf	216	948
DA17-03	<175 um	URS-01	486181	5279483	Qsf	-52	162
DA17-04	<175 um	URS-01	486176	5279503	Qgcc1	730	3730
DA17-05	<175 um	URS-01	486164	5279486	Qsf	137	1050
DA17-06	<175 um	URS-01	486181	5279472	Qsf	119	470
DA17-07	<175 um	URS-01	486171	5279457	Qsf	93	252
DA17-07	<175 um	URS-01	486171	5279457	Qsf	68	182
DA17-08	<175 um	URS-01	486171	5279501	Qgcc1	138	989
DA17-09	<175 um	URS-01	486173	5279483	Qsf	79	855
DA17-10	<175 um	URS-01	486175	5279476	Qsf	114	411
DA17-11	<175 um	URS-01	486176	5279470	Qsf	-59	299
DA17-12	<175 um	URS-01	486177	5279464	Qsf	-57	193
DA17-13	<175 um	URS-01	486180	5279458	Qsf	-62	146
DA17-14	<175 um	URS-01	486181	5279451	Qsf	132	262
DA18-01	<175 um	URS-01	484971	5280020	Qsc	95	418
DA18-02	<175 um	URS-01	484961	5280021	Qsc	479	2030
DA18-03	<175 um	URS-01	484962	5280026	Qsc	361	1920
DA18-03	<175 um	URS-01	484962	5280026	Qsc	348	1880
DA18-04	<175 um	URS-01	484961	5280005	Qsc	144	1090
DA18-05	<175 um	URS-01	484972	5280006	Qsc	358	1610
DA18-06	<175 um	URS-01	484963	5280008	Qsc	398	1920
DA18-07	<175 um	URS-01	484951	5280024	Qsc	246	1240
DA20-01	<175 um	URS-01	483427	5280750	Qsc	175	859
DA20-02	<175 um	URS-01	483432	5280749	Qsc	343	964
DA20-03	<175 um	URS-01	483431	5280744	Qsc	296	1110
DA20-04	<175 um	URS-01	483432	5280752	Qsc	362	1460
DA20-05	<175 um	URS-01	483430	5280751	Qsc	239	1000
DA20-06	<175 um	URS-01	483428	5280755	Qsc	168	941
DA20-07	<175 um	URS-01	483425	5280757	Qsc	156	578
DA20-07	<175 um	URS-01	483425	5280757	Qsc	162	552
DA21-01	<175 um	URS-01	481827	5282445	Qsc	479	1620
DA21-02	<175 um	URS-01	481826	5282442	Qsc	696	2020
DA21-03	<175 um	URS-01	481826	5282444	Qsc	451	1750
DA21-04	<175 um	URS-01	481832	5282448	Qsc	642	1970
DA21-05	<175 um	URS-01	481832	5282446	Qsc	774	2080
DA21-06	<175 um	URS-01	481826	5282446	Qsc	411	1520
DA21-07	<175 um	URS-01	481830	5282445	Qsc	552	1770
DA21-07	<175 um	URS-01	481830	5282445	Qsc	522	1780
DA23-01	<175 um	URS-01	481539	5282101	Qsc	423	1770
DA23-02	<175 um	URS-01	481520	5282062	Qsc	416	1270
DA23-03	<175 um	URS-01	481534	5282077	Qsc	489	1740
DA23-04	<175 um	URS-01	481501	5282063	Qsc	918	2970
DA23-05	<175 um	URS-01	481511	5282054	Qsc	452	1550
DA23-05	<175 um	URS-01	481511	5282054	Qsc	436	1440
DA23-06	<175 um	URS-01	481536	5282069	Qsc	124	544
DA23-07	<175 um	URS-01	481543	5282084	Qsc	476	1870

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Table 1: Geochemical data for sediment samples from the Spokane River in the map area.

SAMPLE_ID	GRAINSIZE	As_ppm	Cd_ppm	Fe_%	Hg_ppm	Mn_ppm	Sb_ppm	Al_%
SRG-37	<2000 um	11	0.8	2.7	0.02	490	1.6	6.1
SRG-38	<2000 um	12	2.8	2.4	0.02	710	2.0	6.4
SRG-39	<2000 um	13	1.3	2.8	0.03	720	1.8	6.4
SRG-40	<2000 um	9.6	13	2.0	0.05	910	2.1	5.5
SRG-41	<2000 um	9.9	2.2	2.4	0.02	770	2.2	6.2
SRG-42	<2000 um	12	23	2.6	0.20	350	6.5	6.1
SRG-43	<2000 um	9.7	1.7	2.6	0.03	500	1.9	6.6
SRG-44	<2000 um	6.5	2.5	2.7	0.03	550	2.1	6.5
SRG-45	<2000 um	6.2	3.2	2.3	0.03	340	2.3	6.3
SRG-46	<2000 um	6.8	1.6	2.5	0.01	430	1.5	6.5
SRH-02	<2000 um	28	9.0	3.0	0.33	2300	9.2	7.1
SRH-03	<2000 um	16	5.3	3.2	0.13	1400	3.4	6.5
SRH-04	<2000 um	15	4.5	2.8	0.08	1100	2.5	6.8
SRH-05	<2000 um	30	6.8	3.6	0.15	1800	5.4	6.7
SRH-06	<2000 um	8.3	-0.1	2.9	0.01	700	1.3	6.0
SRH-14	<2000 um	12	3.8	3.1	0.07	990	2.2	6.6
SRH-15	<2000 um	18	9.6	3.4	0.23	1300	4.8	5.9
SRH-15a	<2000 um	19	9.1	3.2	0.26	1200	4.8	5.8
SRH-16	<2000 um	21	8.8	3.2	0.23	2100	8.3	7.0
SRH-17	<2000 um	17	3.0	3.4	0.08	780	3.7	7.3
SRH-18	<2000 um	10	3.3	2.7	0.04	810	2.3	6.6
SRH-19	<2000 um	14	4.6	2.9	0.08	1300	3.6	6.7
SRH-20	<2000 um	16	18	2.8	0.04	1500	3.9	5.6
SRH-21	<2000 um	17	6.2	3.4	0.12	1500	3.8	6.6
SRH-21a	<2000 um	36	12	3.8	9.20	3000	8.2	7.1
SRH-22	<2000 um	26	7.7	6.2	0.03	1900	4.9	14.7
SRH-23	<2000 um	16	3.2	3.0	0.10	1100	3.1	6.6
SRH-24	<2000 um	19	6.2	3.2	0.17	1700	4.5	6.8
SRH-25	<2000 um	13	3.4	2.6	0.03	810	2.2	6.4
SRH-26	<2000 um	8.9	2.0	3.0	0.01	650	1.8	6.6
SRH-26a	<2000 um	9.4	1.9	2.6	0.01	590	1.6	6.4
SRH-27	<2000 um	13	4.7	2.8	0.03	890	2.3	6.4
SRH-28	<2000 um	15	2.7	2.5	0.03	820	2.0	6.3
SRH-29	<2000 um	14	5.1	3.3	0.06	980	3.4	6.8
SRH-30	<2000 um	11	1.8	2.6	0.01	490	1.7	6.5
SRG-38	<63 um	43	15	3.9	0.15	2400	5.8	6.3
SRG-39	<63 um	53	19	3.9	0.10	2200	4.9	6.3
SRG-40	<63 um	11	38	1.9	0.15	2100	2.7	3.0
SRG-41	<63 um	32	37	3.5	0.27	3600	11.0	6.2
SRG-42	<63 um	11	17	2.6	0.17	320	5.0	7.0
SRG-43	<63 um	19	5.9	3.7	0.05	1100	4.0	8.1
SRG-44	<63 um	20	36	3.4	0.25	1300	5.5	5.3
SRG-45	<63 um	11	20	2.8	0.25	520	4.9	5.3
SRG-46	<63 um	20	20	3.5	0.20	840	4.5	6.6
SRH-02	<63 um	60	28	4.7	0.99	4900	21.0	7.9
SRH-03	<63 um	38	19	4.1	0.54	3600	8.3	7.5
SRH-04	<63 um	50	20	4.4	0.53	3800	7.5	7.6
SRH-05	<63 um	39	7.9	4.2	0.26	1600	7.9	7.1

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